Climate feedback of tropical deep convection —— moisture budget analysis

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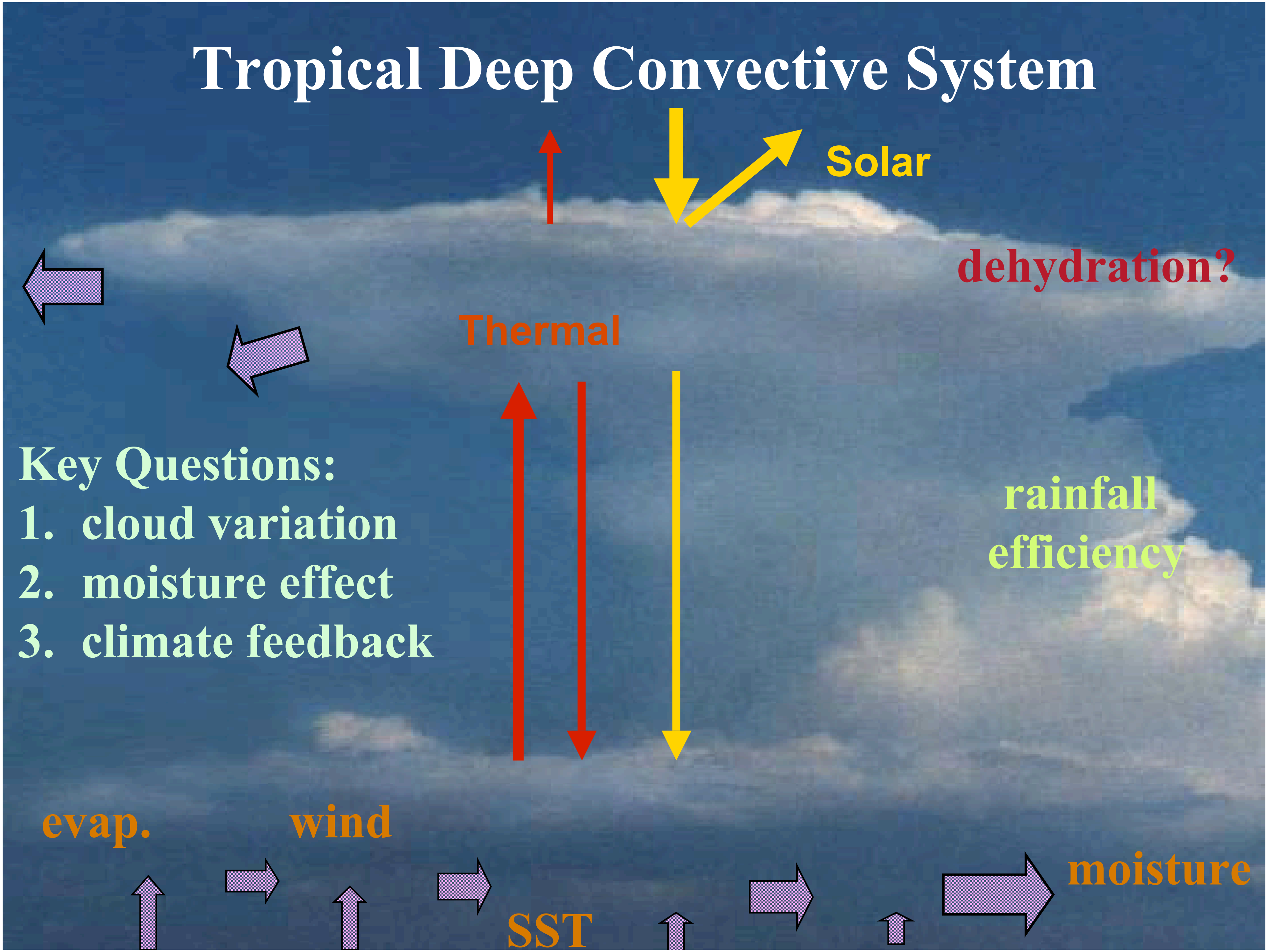
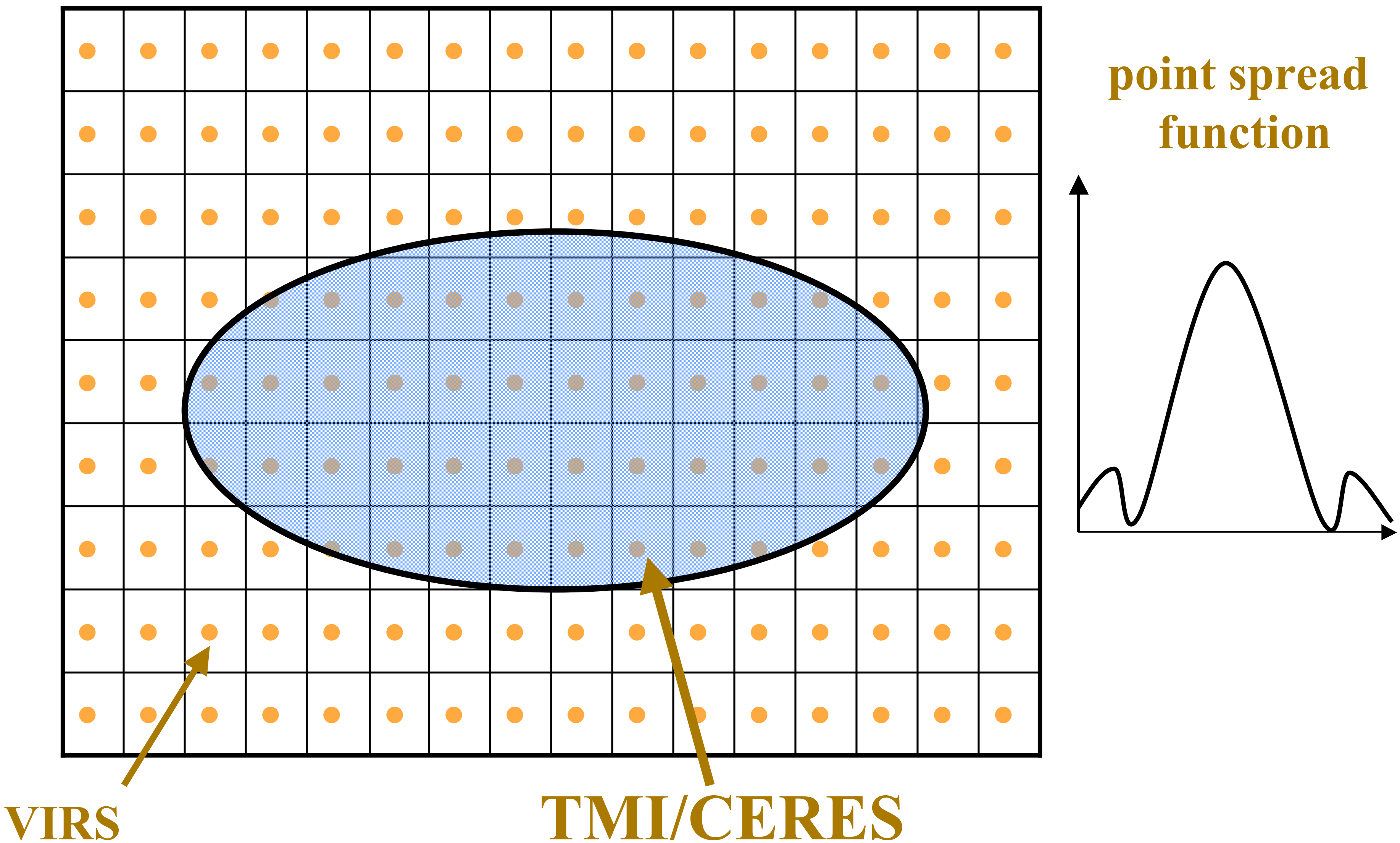
CERES Science Meeting


Tropical Deep Convective System
Solar
dehydration?
Thermal
Key Questions:
1. cloud variation
2. moisture effect
3. climate feedback
rainfall
efficiency
evap.
wind
moisture
SST

Data match —— convolution

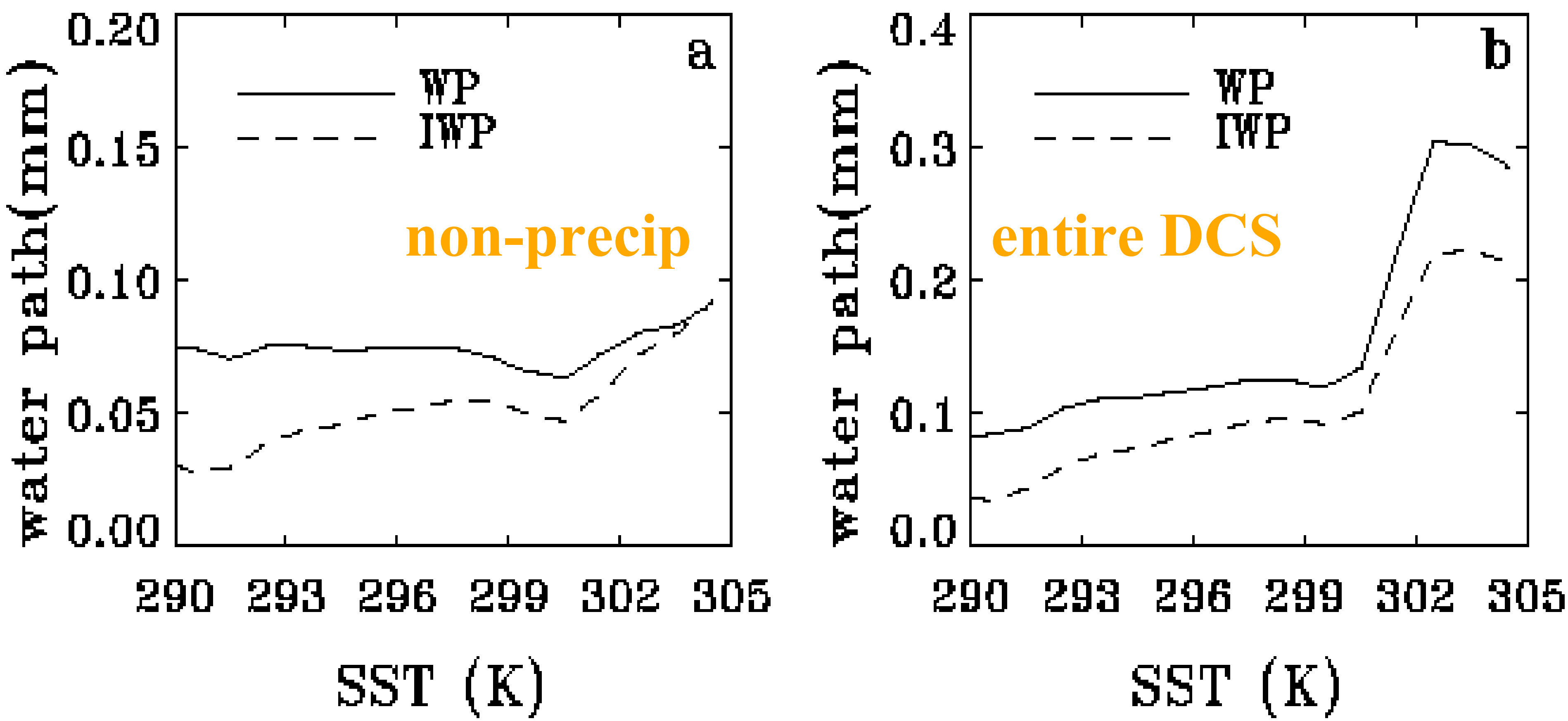


Multi-Sensor Data Fusion

- Convolution of multi-sensor measurements into TMI 37GHz FOV
- Rainfall rate: TMI & PR
- Cloud detection, top temperature and optical depth: VIRS
- Cloud liquid/ice water path: VIRS and TMI
- Evaporation and boundary layer moisture: TMI
- Radiation fields: CERES

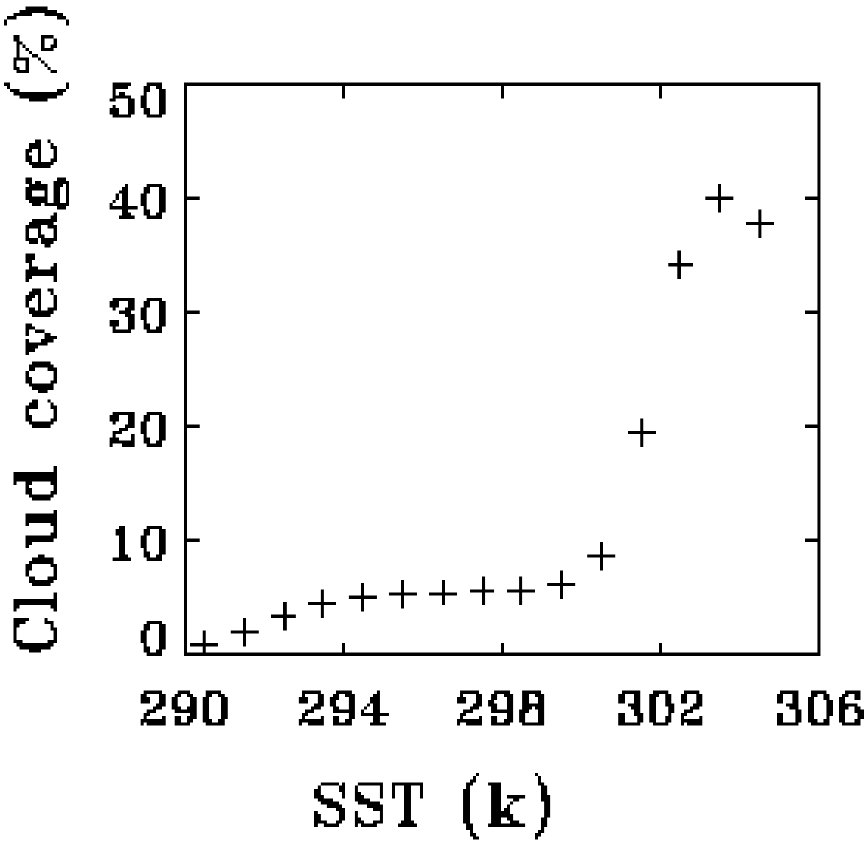
- Vector wind fields: assimilation products

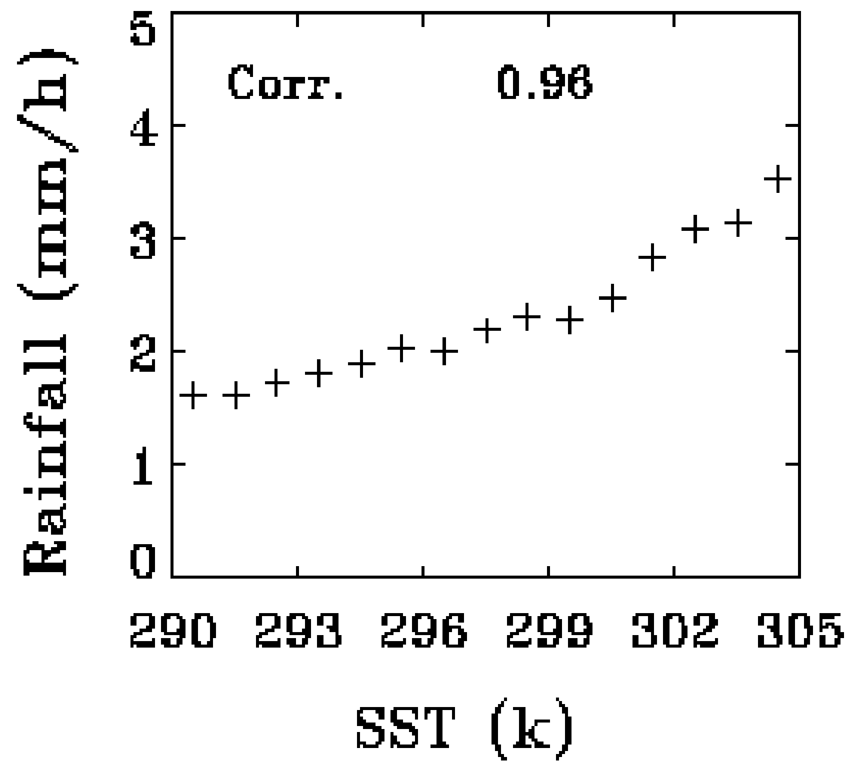
DCS WP & IWP



Deeper convection under higher SST conditions generally produces thicker anvils, and is likely moistening upper troposphere more.

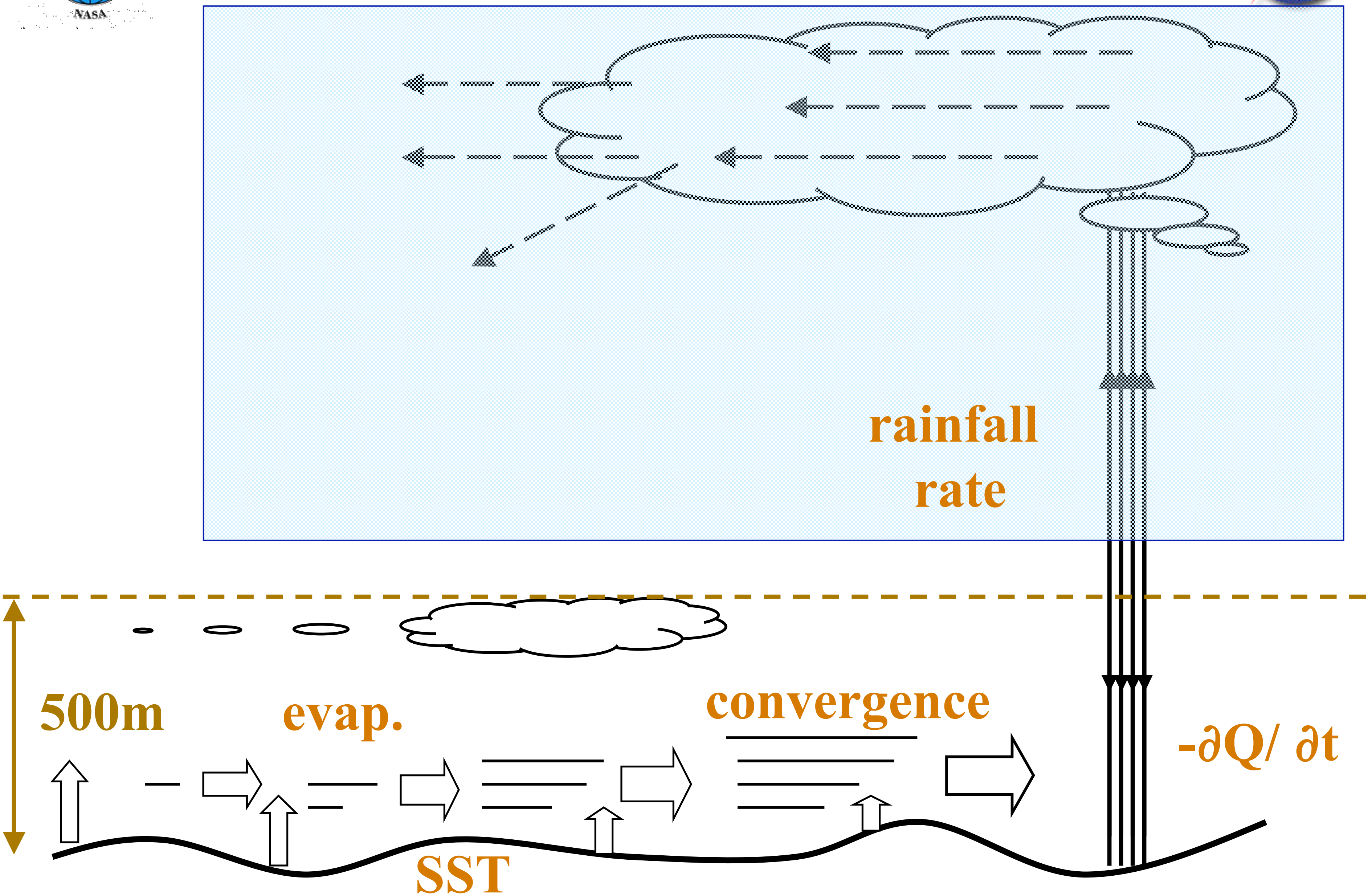
DCS areal coverage & rain rate



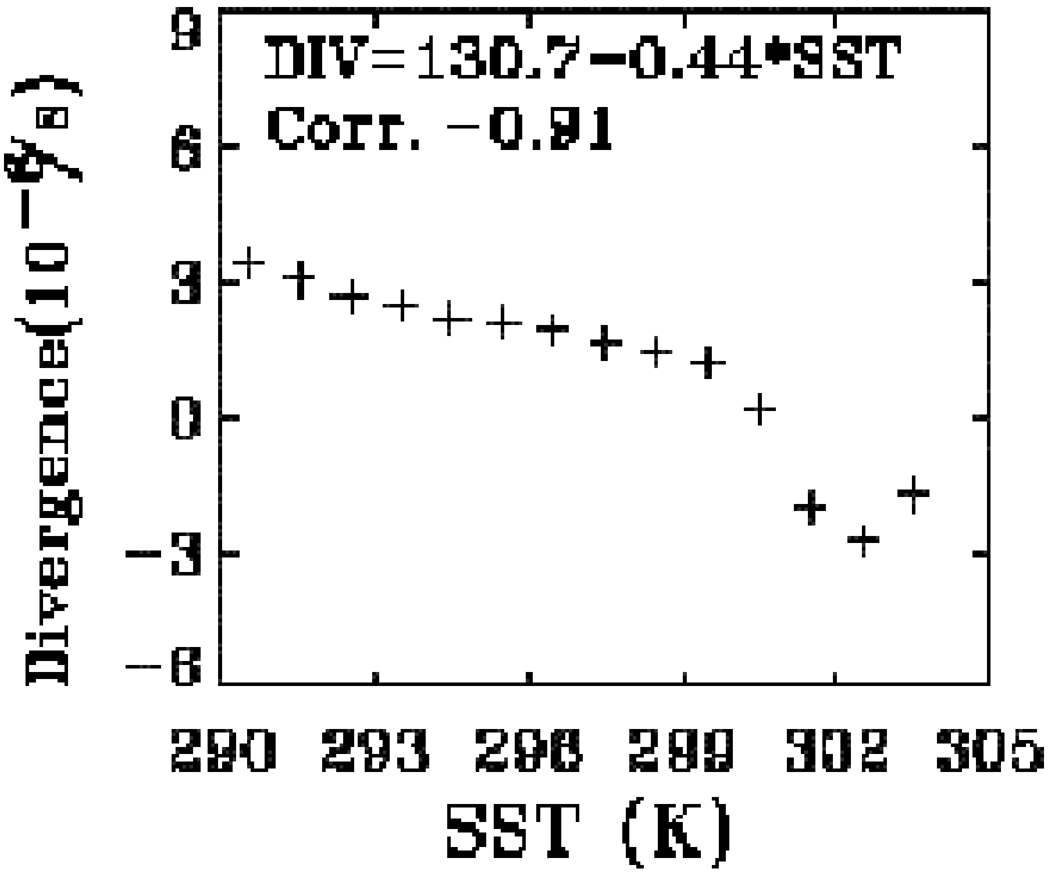


Deeper convection under higher SST conditions could cause higher rainfall efficiency, which would result in DCS reductions in warmer environments. Why is there no evidence of DCS dehydrations?

Moisture Balance



divergence



Convergence:
sharp increases in warm SSTs

Rainfall efficiency

- **Moisture supply to DCS clusters:**

  $$M_s = -\partial Q_b/\partial t + E_s - \nabla \bullet Q_b V \qquad (1)$$

  tendency, evaporation and horizontal transport

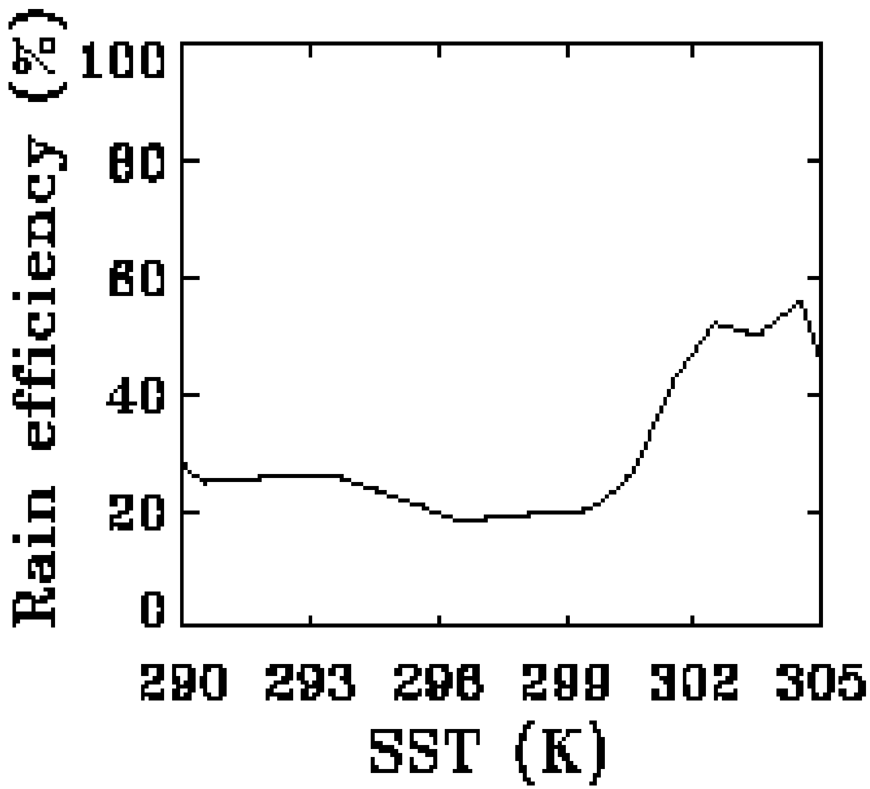
- $\eta = RR/Ms$

  $$= RR/(-\partial WV_L/\partial t + E_s - \nabla \bullet WV_L V) \qquad (2)$$

  TMI: Es and WV_L for lowest 500m PBL

  ECMWF: $\nabla \bullet WV_L V$

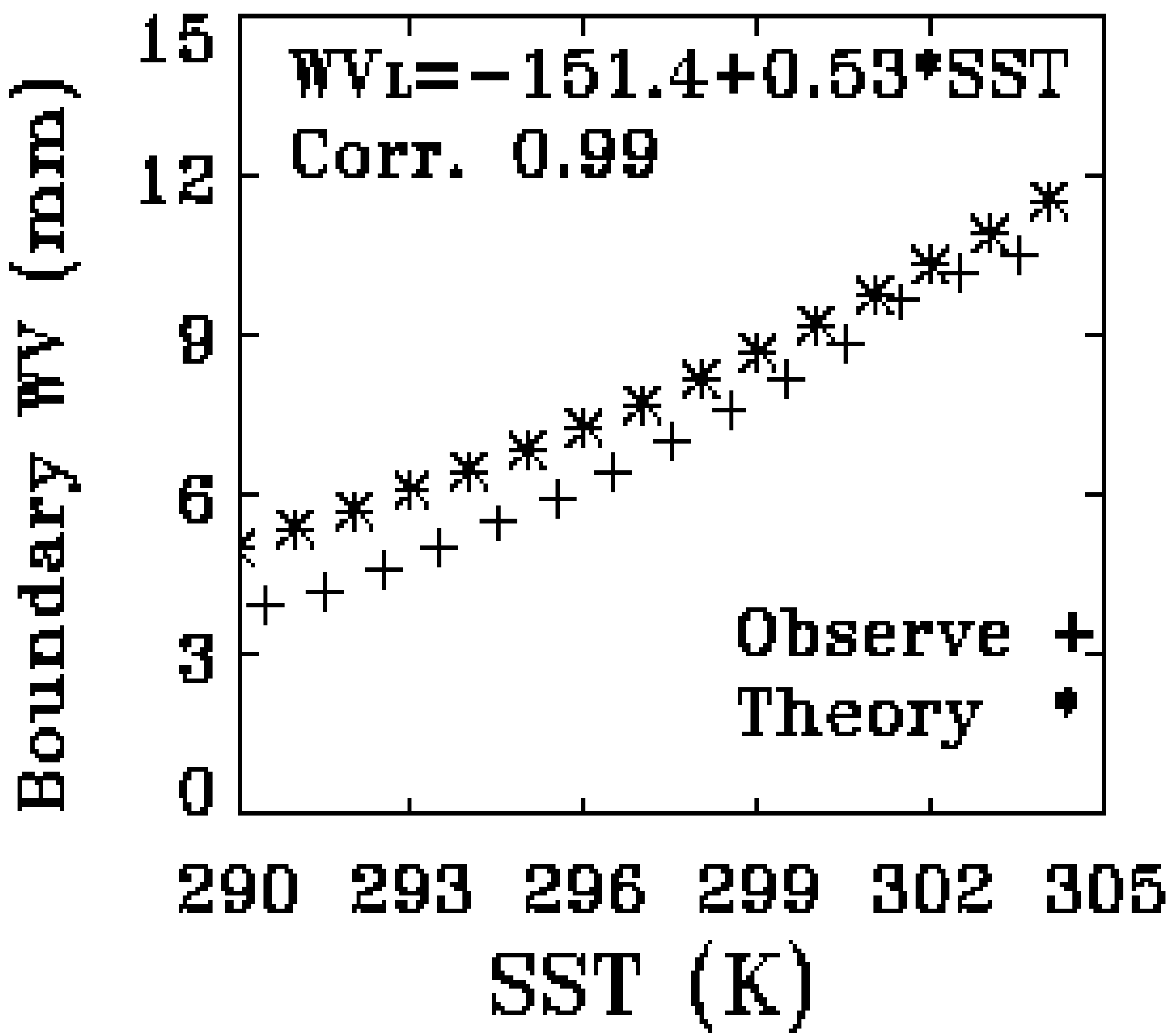
Rainfall efficiency



mean: ~35%
increase: ~ 2%/K
sharp for warm SST

Why is there no evidence of DCS dehydrations?

Boundary layer moisture



Moisture change with Temp

- $Q_b = rh * Q_{sa}$

  Q_{sa}: saturated Q; rh: relative humidity

  $\Delta Q_b = rh * 6.3\% \; Q_{sa} = 6.3\% \; Q_b$ (3)

- $E_s = \rho_a C_l (Q_{ss} - rh * Q_{sa}) W_s$

  $\Delta E_s = 6.3\% \; E_s$ (4)

- $\Delta M_s = 6.3\% \; M_s$ (5)

So, all moisture related terms increase ~6.3%/K.

Moisture transport for anvils

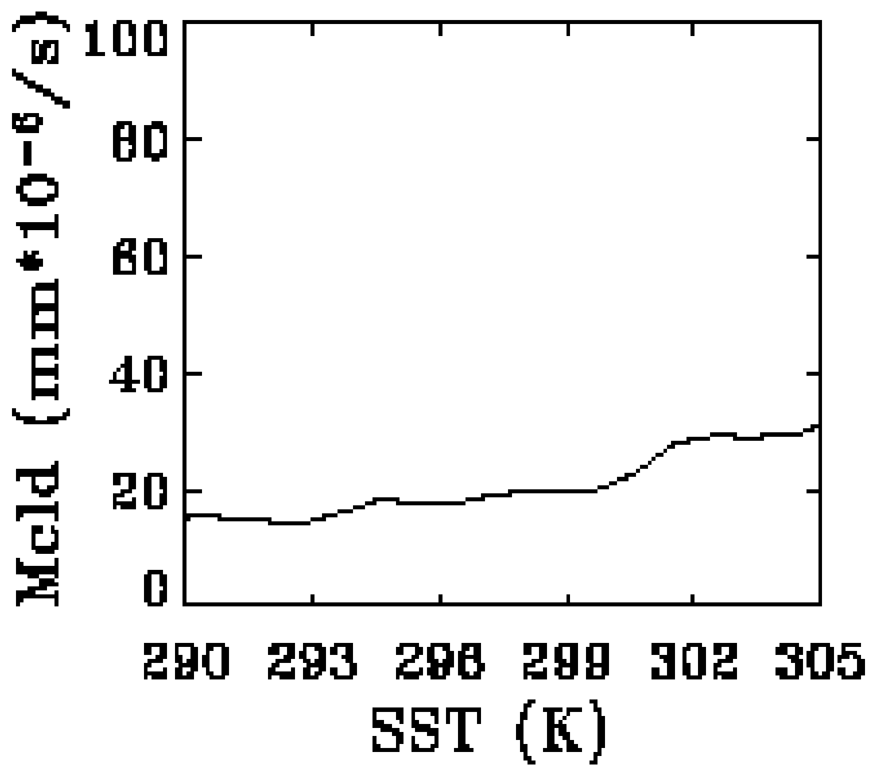
- $M_{cld} = Ms - RR = Ms\,(1 - \eta)$ (6)

  where M_{cld} is moisture supply to cirrus-anvil clouds

- $\Delta M_{cld} = \Delta(Ms\,(1 - \eta))$ (7)

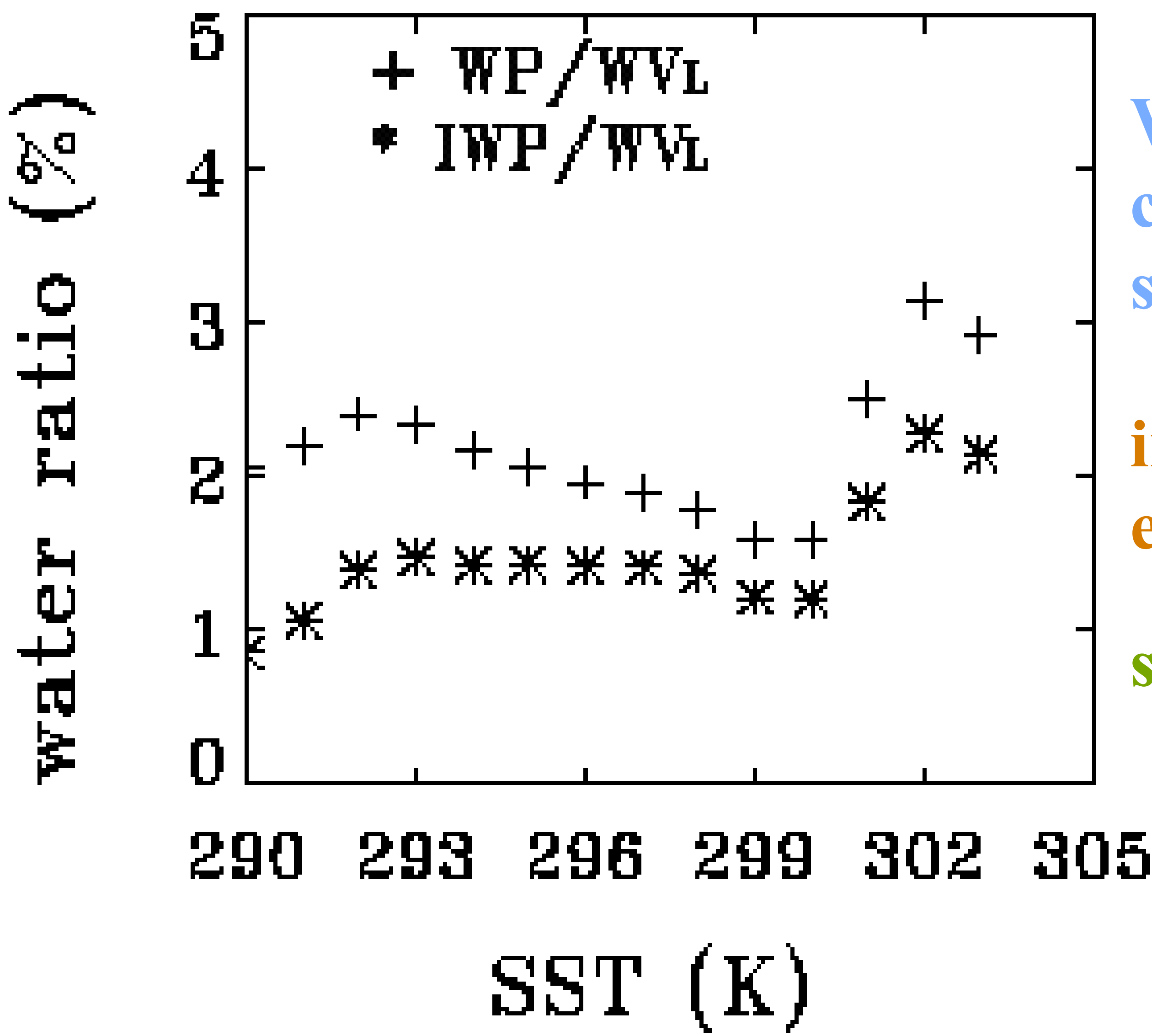
- $\Delta M_{cld}/M_{cld} = \Delta M_{cld}\,/(Ms\,(1 - \eta))$
- $= \Delta Ms/Ms - \Delta\eta/(1 - \eta)$
- $\approx 6.3\% - 2\%/(1 - 0.35) \approx 3.0\%$ (8)

Moisture supply for cirrus-anvil clouds



~ 4%/K increase rate

Water ratio

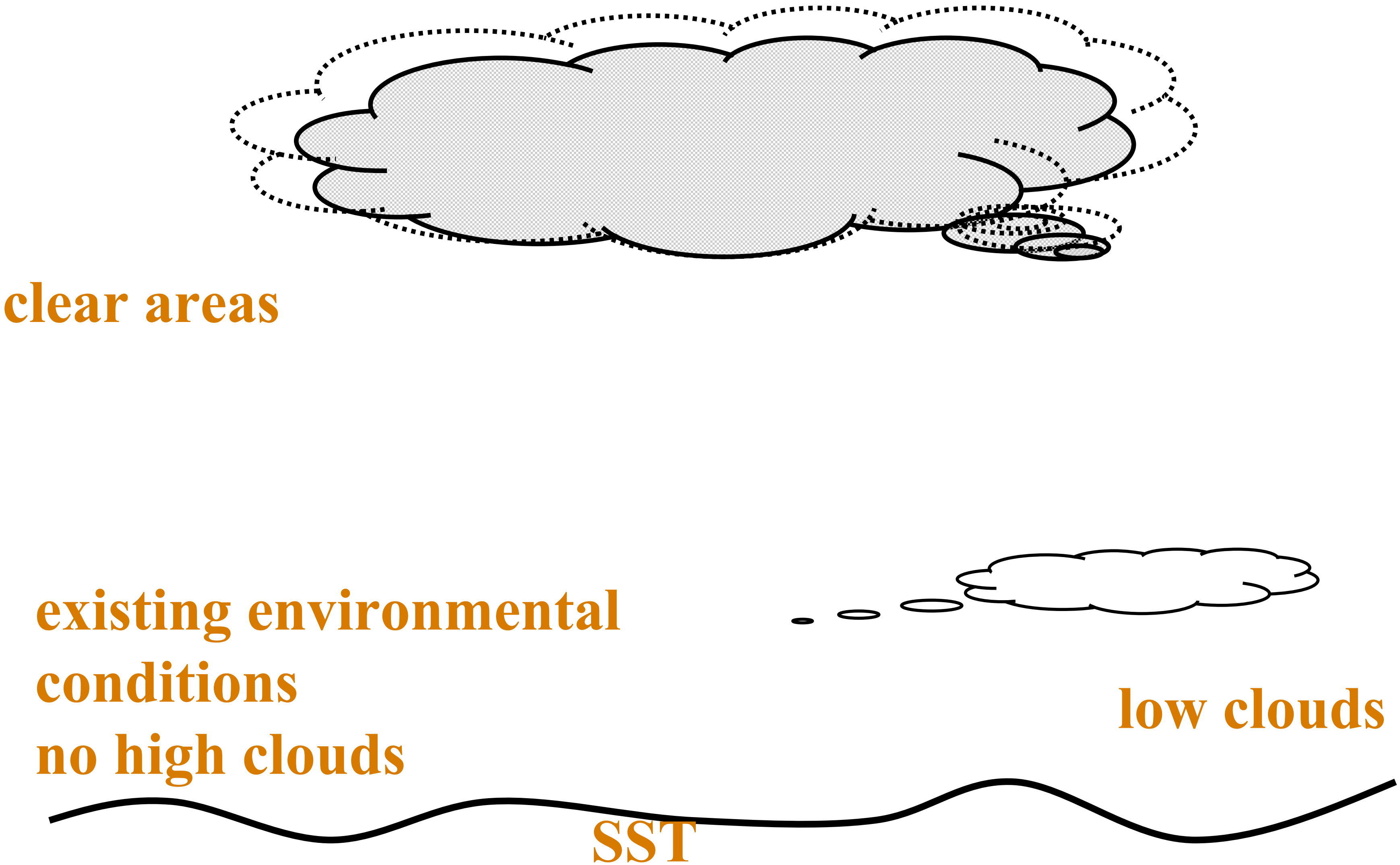


Why DCS area coverage increase so fast with SST?

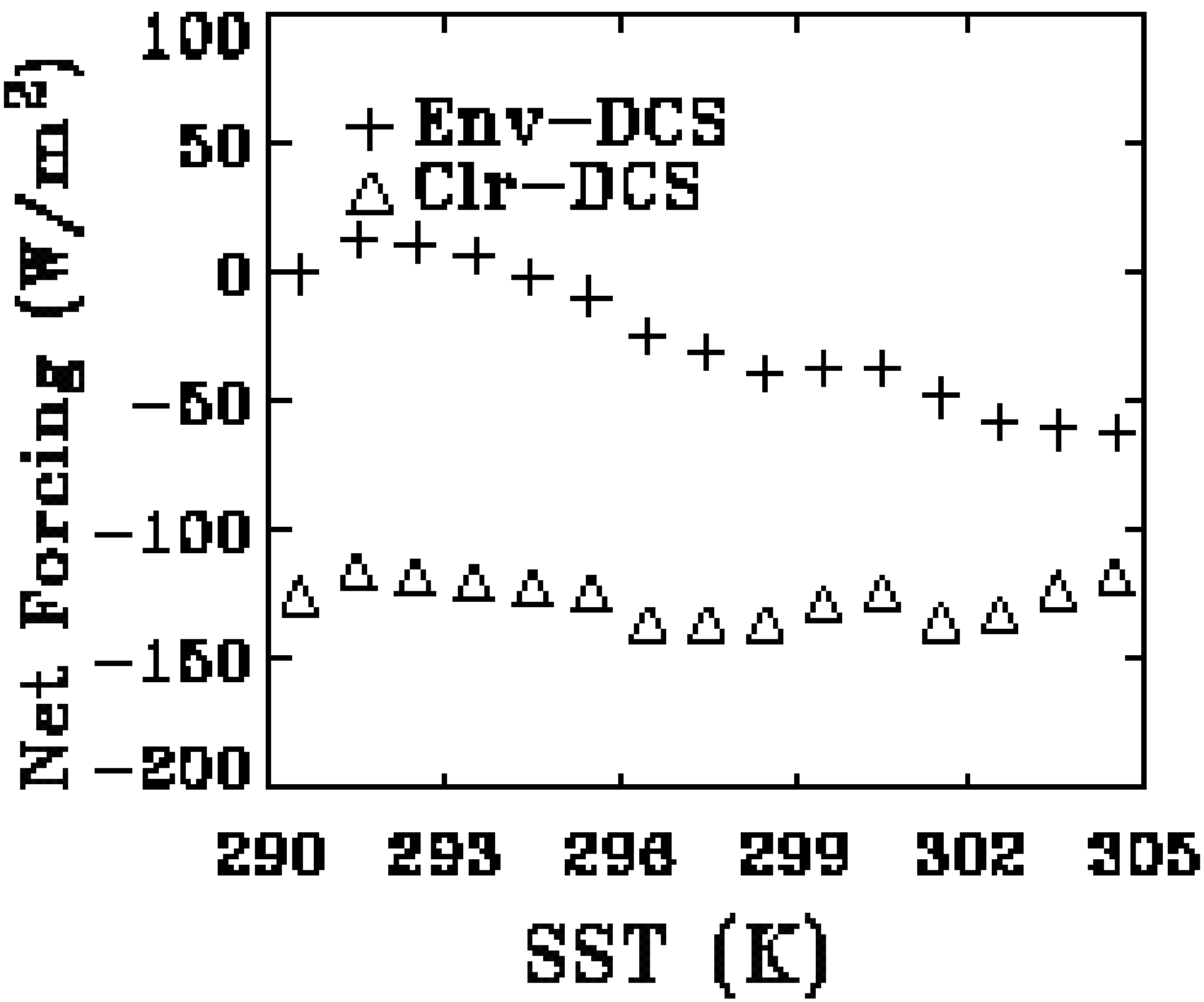
increase in cloud efficiency?

some indication

Generalized radiative forcing



Net radiation



Note: Clr, Env and DCS represent values for clear, environmental and DCS skies. Thus, F = Clr – DCS; G = Env – DCS

Summary

- Although DCS precipitation and rainfall efficiency increase with temperature, DCS area coverage still increases with SST.
- The boundary layer moisture supply for DCS increases faster than rainfall efficiency and results in increases of the moisture transported to the upper troposphere for cirrus-anvil formation.
- The average change in net radiative forcing due to DCS change from existing environmental conditions is relatively weak (about –0.56 $W/m^2/K$).

→ a weak negative DCS feedback

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Many people, especially Sunny Sun-Mack, Jianping Huang, Dave Young, and Gary Gibson have significant contributions to this study.

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